5.4.3 Planetary motion

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	Kepler's three laws of planetary motion	HSW7
(b)	the centripetal force on a planet is provided by the gravitational force between it and the Sun	
(c)	the equation $T^2 = \left(\frac{4\pi^2}{GM}\right) r^3$	Learners will also be expected to derive this equation from first principles. HSW1
(d)	the relationship for Kepler's third law $T^2 \propto r^3$ applied to systems other than our solar system	
(e)	geostationary orbit; uses of geostationary satellites.	HSW1, 2, 9, 10 Predicting geostationary orbit using Newtonian laws.

(6) M - Define geostationary orbits and describe their use.
(7) S - Apply Keplers 3rd law to satellites
(8) C - Predict geostationary orbits using Newtonian laws

Lesson 4. Satellites

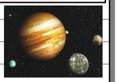
0:00:00

STARTER: Use the data to show the motion of Jupiter's moons follow Kepler's 3rd law.
HWK (due next lesson):
PPQ and glossary

Moon	r/m	T/days
Io	4.2×10^8	1.77
Europa	6.7×10^8	3.55
Ganymede	1.1×10^9	7.2
Callisto	1.9×10^9	16.7

Kilo 10^3
Mega 10^6 What is the mass of Jupiter?
Giga 10^9 A fifth moon - Amalthea has an orbital period of 0.5 days -what is its orbital radius?

Key point



a Plot T^2 against r^3, which gives a straight line through the origin. (Alternatively, determine the average value of T^2/r^3, which is $3.06\times10^{-16}\,s^2\,m^{-3}$.)
b 1.9×10^{27} kg
c 1.8×10^8 m

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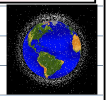
SPY. GPS. satellite physics 0:00:00

ACTIVITY:
What are satellites used for? → Communication → Monitoring / Surveying
Define a **geostationary** satellite?
What are the conditions needed for the above orbit?

Kilo 10^3
Mega 10^6
Giga 10^9 A geostationary satellite has a mass of 80kg - calcuate its KE.



Key point

Geostationary Satellites

A geostationary satellite stays locked into the Earth's period of rotation so that it appears to be in the same position relative to Earth. Conditions:

- Orbital period 24 hours
- Orbits above the equator (plane equatorial). Centre of orbit must be centre of Earth
- Orbits in the same direction as the Earth rotation

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Putting a satellite in orbit

ACTIVITY: A 60kg satellite in a stable orbit suddenly loses 20kg of mass by a part slowly breaking off.

What happens to its orbital radius? does not change -

Kilo 10^3
Mega 10^6 Justify your answer mathematically.
Giga 10^9

Equate centripetal force with gravitational force

Key point

Rearrange for v

$$F = \frac{mv^2}{r} = \frac{GMm}{r^2}$$

$$\frac{mv^2}{r} = \frac{GMm}{r^2}$$

$$mv^2 = \frac{GMm}{r}$$

$$v^2 = \frac{GM}{r} \quad \Rightarrow v = \sqrt{\frac{GM}{r}}$$

Since GM is a constant - a particular radius of orbit requires a particular speed.

The mass of the satellite is independent of the speed or orbital radius

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Worked example: Height of geostationary satellites

The radius of the Earth is 6370 km, and it has mass 5.97×10^{24} kg. Calculate the altitude (height above the ground) of geostationary satellites above the equator.

$T = 24hrs = 86400\,S$

1. Rearrange keplers 3rd law equation to make r the subject

r A

$$r \sqrt[3]{\frac{GMT^2}{4\pi^2}} =$$

2. Knowing the orbital period is 24hrs, substitute this into the equation.

Key point

3. Subtract the radius of the Earth to find height.

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ACTIVITY: Worksheet

HWK (due next lesson):

Kilo 10^3
Mega 10^6 Lowe:
Giga 10^9

Key point

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Plenary 0:00:00

Key point

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